



U.S. Department of Energy
**Energy Efficiency
and Renewable Energy**

Bringing you a prosperous future where energy
is clean, abundant, reliable, and affordable

FreedomCAR & Vehicle Technologies Program

Motivations for Promoting Clean Diesels

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U.S. Department of Energy

Presented at the
EPA Region 5 Diesel Conference
Chicago, IL
September 6-7, 2006

FCVT Program Mission

*To develop more energy efficient and environmentally friendly highway
transportation technologies that enable America to use less petroleum.*

--EERE Strategic Plan, October 2002--



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Outline

- ❑ Our Oil Situation
- ❑ Rationale for Clean Diesels
- ❑ Progress in Reducing Diesel Emissions
- ❑ Summary



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Are We Running Out Of Oil?



It took us 125 years to use the first trillion barrels of oil.

We'll use the next trillion in 30.

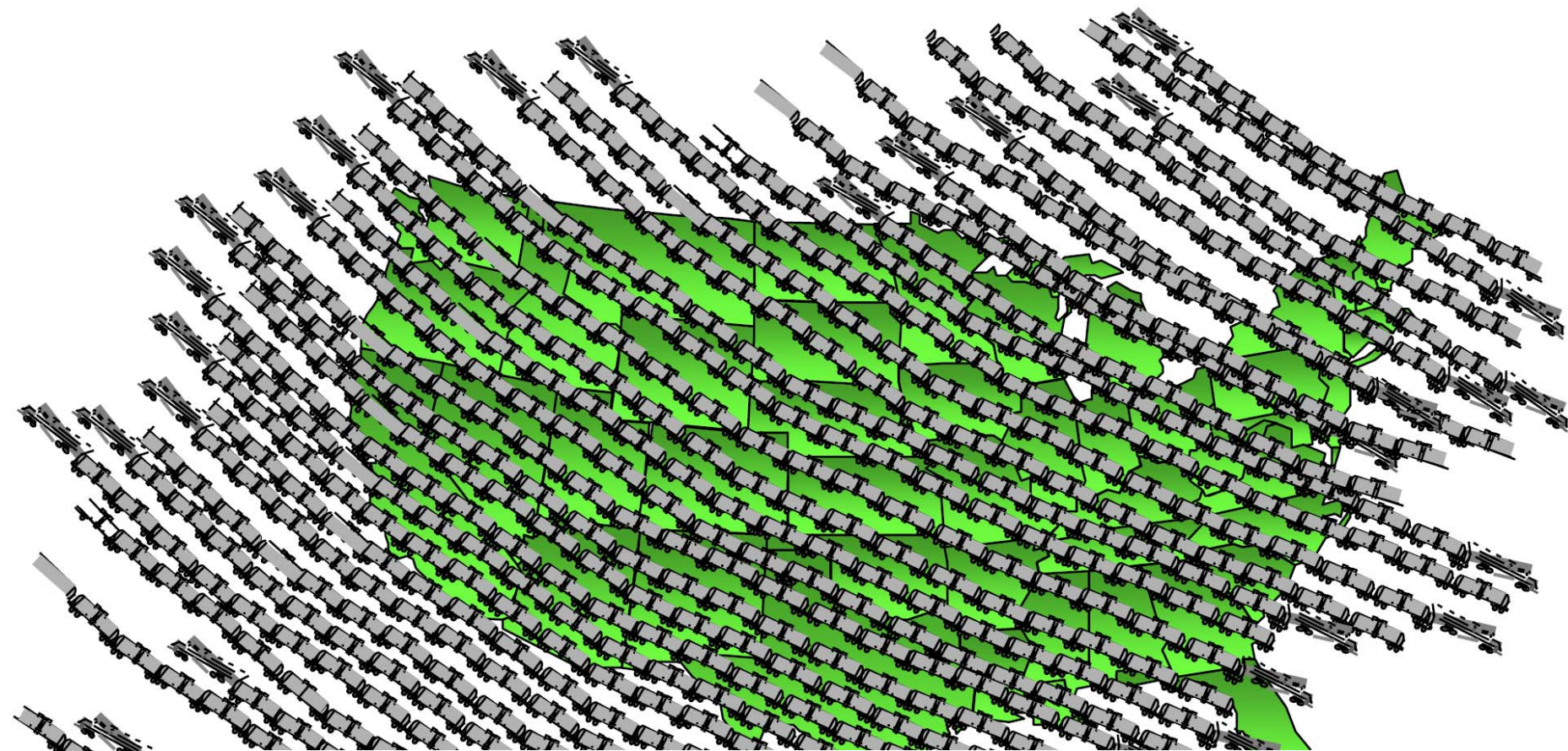
Source: www.willyoujoinus.com



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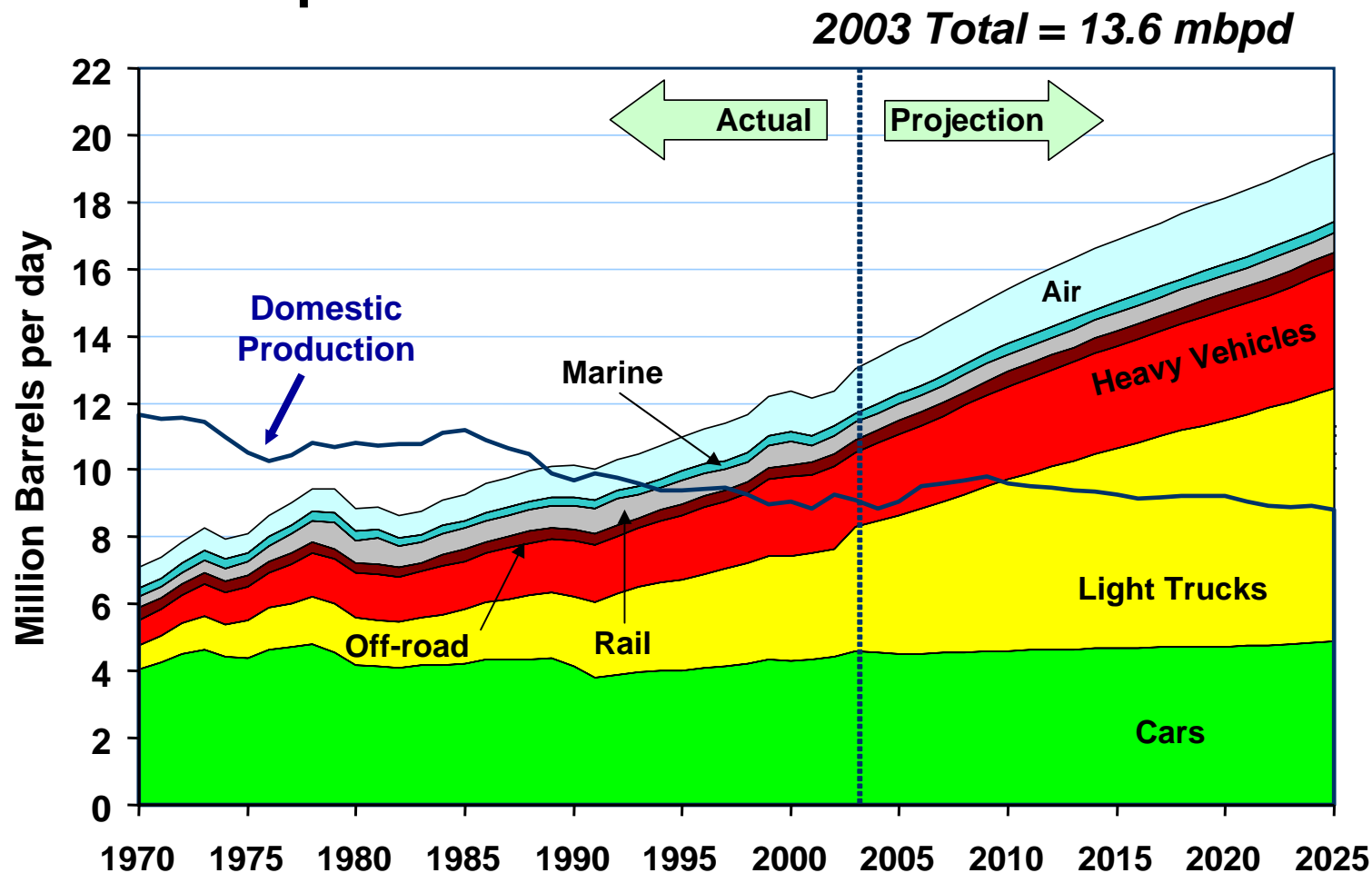
The Magnitude of Our Energy Problem



In 2004 the U.S. crude oil consumption would have filled over 10.5 million tank cars which would stretch between Miami and Seattle (3,300 miles) over 36 times.



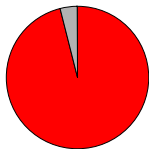
U.S. Transportation Oil Use





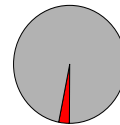
Oil Consumption by End-Use Sector, 2004

Transportation



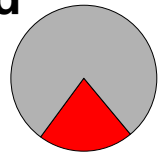
96% Oil Dependent

Electric Power

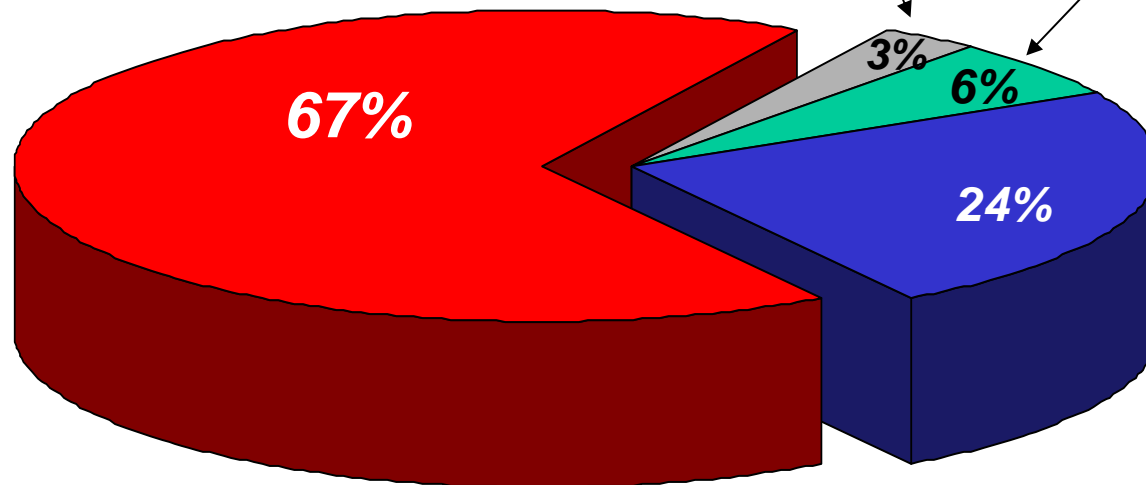


3% Oil Dependent

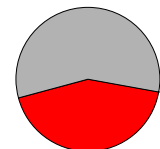
Residential and Commercial



21% Oil Dependent



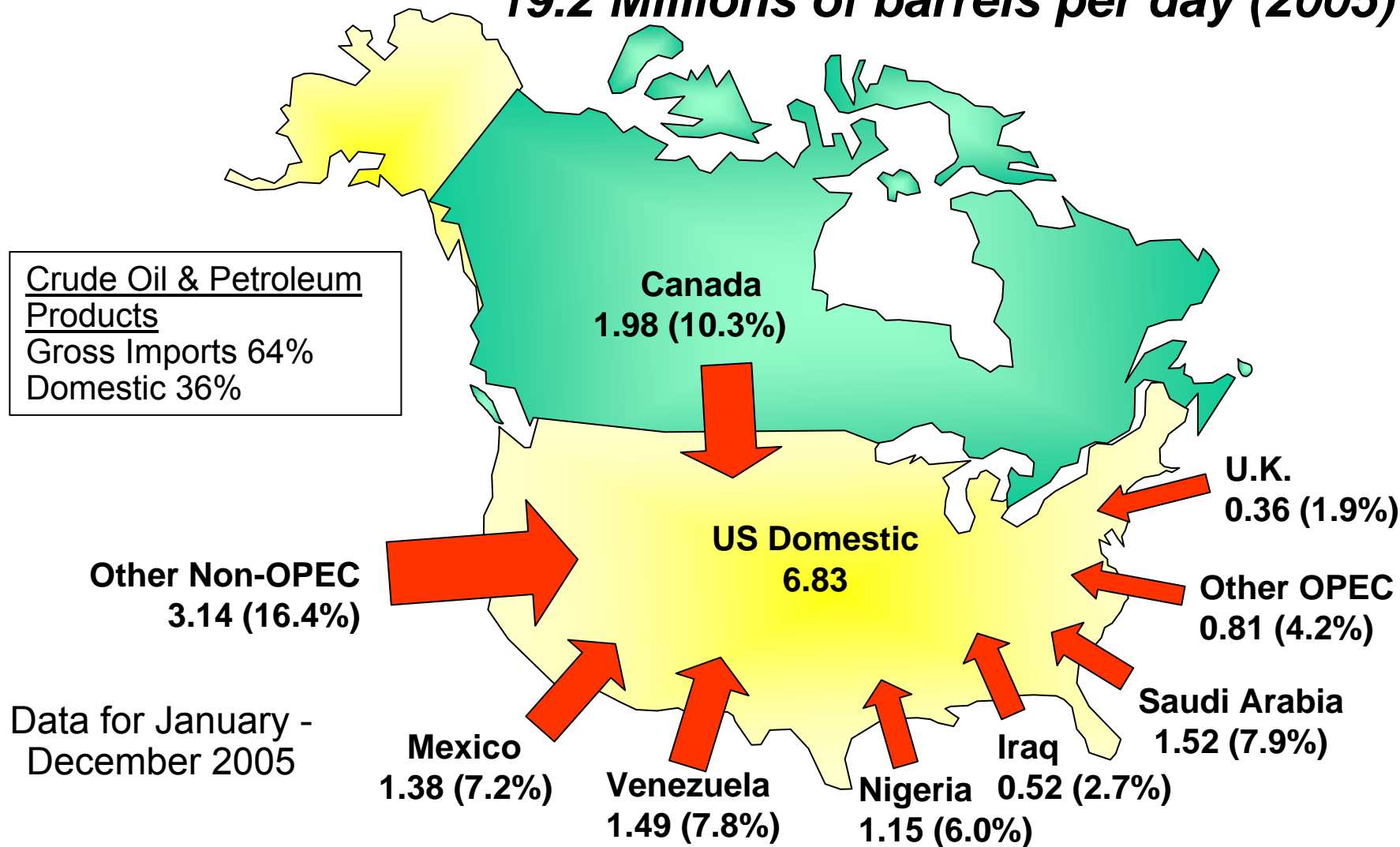
Industry



43% Oil Dependent

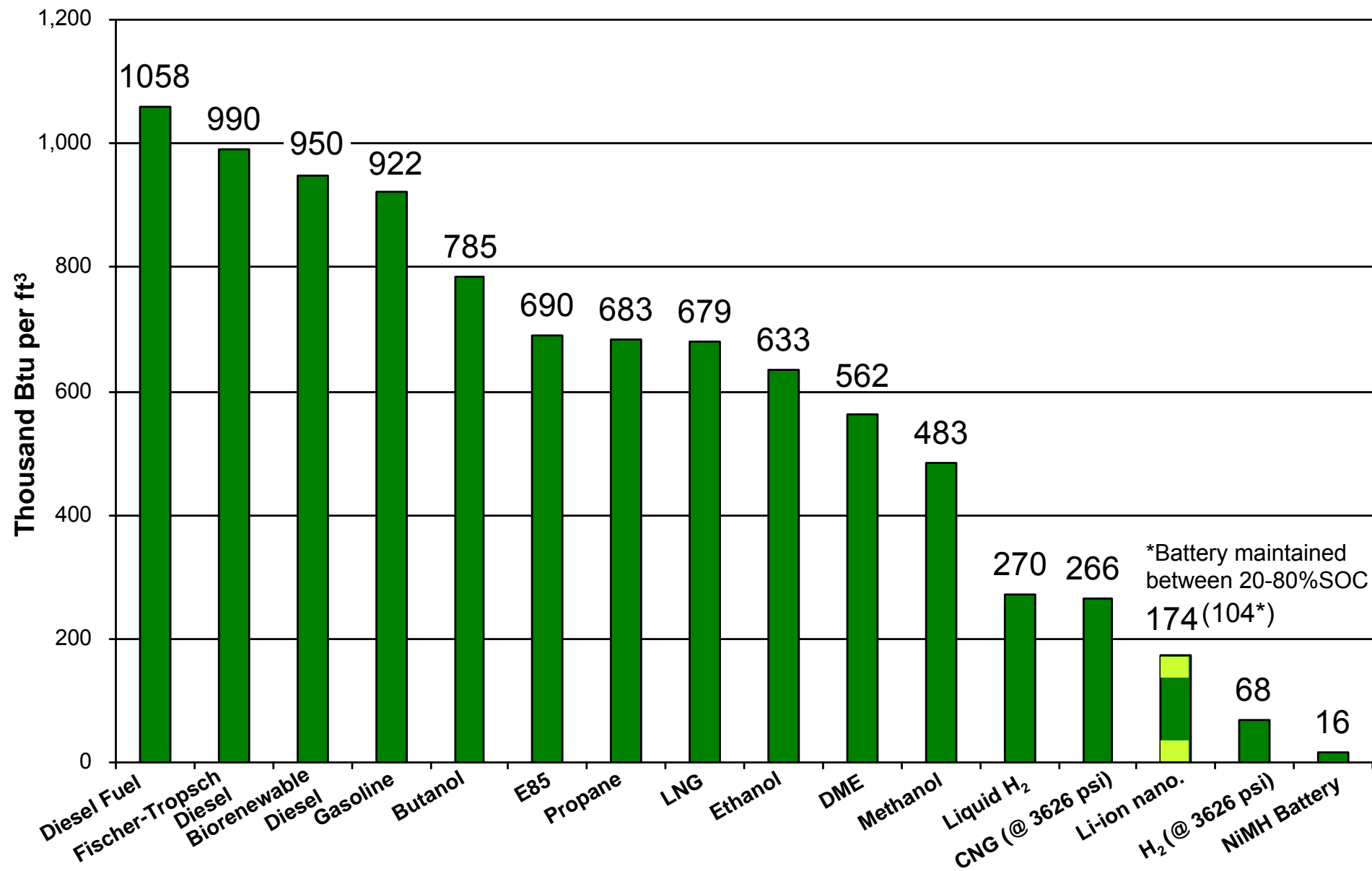


19.2 Millions of barrels per day (2005)





Energy Density of Fuels





...were diesel engines to account for even one-third of all vehicle miles traveled, it would save one million barrels of oil per day in the U.S. — equivalent to the amount imported from Iraq before the war.

“Clean Diesel”?

“Clean diesel” is a catchphrase much in vogue in Washington, D.C. these days. Margo Oge, director of the EPA’s Office of Transportation and Air Quality, has been one of the government’s most vocal advocates of the new generation of diesels and has gone on record comparing their environmental friendliness with that of the cleanest gasoline and alternative-fueled engines. She has noted that, were diesel engines to account for even one-third of all vehicle miles traveled (“VMT”), it would save one million barrels of oil per day in the U.S.—equivalent to the amount imported from Iraq before the war.



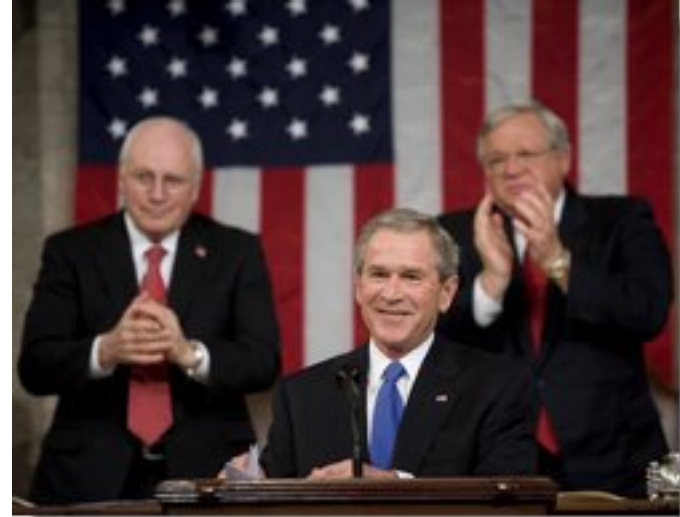
Source: Aluminum Now Online, Vol. 7, No. 4, July/August 2005

<http://www.aluminum.org/ANTemplate.cfm?IssueDate=07/01/2005&Template=/ContentManagement/ContentDisplay.cfm&ContentID=8774>



State of the Union Address January 31, 2006

“Breakthroughs... will help us reach another great goal: **to replace more than 75 percent of our oil imports from the Middle East by 2025.** ...this country can ... move beyond a petroleum-based economy, and make our dependence on Middle Eastern oil a thing of the past.”



President Bush during his State of the Union Address at the Capitol, January 31, 2006. White House photo.

(<http://www.whitehouse.gov/news/releases/2006/01/print/20060131-10.html>)



"If we could convert just one-third of our automotive fleet in the U.S. to clean diesel power, we could save 1.4 million barrels of oil a day," said U.S. Energy Secretary Samuel Bodman.

"If we could convert just one-third of our automotive fleet in the U.S. to clean diesel power, we could save 1.4 million barrels of oil a day."



“The world uses just about 83 million barrels of oil a day, and there’s about 85 million worth of production, so there’s a very tight excess supply... For decades to come, we’re going to be based on fossil fuels providing energy.” - James Mulva, Chairman and CEO, ConocoPhillips Corporation, *Meet the Press, June 18, 2006.*



Senate Committee on
Homeland Security &
Governmental Affairs

Press Releases

June 27, 2006

LEVIN-COLEMAN REPORT FINDS SPECULATION ADDING TO OIL PRICES: PUT THE COP BACK ON THE BEAT

WASHINGTON – Senators Carl Levin (D-Mich.) and Norm Coleman (R-Minn.), Ranking Minority Member and Chairman of the Senate Permanent Subcommittee on Investigations, today released a Subcommittee staff report finding that market speculation has contributed to rising oil and gasoline prices, and that too many energy trades are occurring without regulatory oversight. The report recommends that Congress enact legislation to close a major loophole in federal oversight of oil and gas traders, slipped into law in 2000 at the behest of Enron and other large energy traders.

Many analysts believe these speculative investments have significantly raised the price of oil futures. While it is not possible to determine the precise dollar increase in the price of oil attributable to market speculation, some analysts have estimated that speculation has added as much as \$20-\$25 to the price of each barrel of oil, thereby pushing up oil from about \$50 to around \$70 per barrel. As former Federal Reserve Chairman Alan Greenspan recently stated, "with the demand from the investment community, oil prices have moved up sooner than they would have otherwise."

...speculation has added as much as \$20 - \$25 to the price of each barrel of oil... pushing up oil from about \$50 to around \$70 per barrel.

Source: <http://hsgac.senate.gov>



Engine Technologies

Combustion Engines -- Still the Most Viable for Transportation ***Especially for Heavy-Duty Applications***

New Combustion Regimes Promise High Efficiency and Low Emissions.



- ❑ **Highest efficiency engine today** (44 percent efficient versus 32 percent for production gasoline engines).
- ❑ Can be made more efficient (up to 55 percent efficient)
- ❑ High efficiency is important for greenhouse gases (especially carbon dioxide)
- ❑ Engine-of-choice for heavy vehicles (trucks)
-- offers power, efficiency, durability, reliability.



Why Clean Diesels?

- ❑ Extensive application in rail, marine, and off-highway vehicles.
- ❑ Runs on alternative fuels (natural gas, DME, DEE, F-T diesel, biodiesel).
- ❑ Production infrastructure in place.
- ❑ **CAN BE VERY LOW EMISSIONS.**



Diesel, the Practical Commercial Engine On- and Off- Highway

- ❑ Long-haul tractor-trailer trucks are almost exclusively diesel
- ❑ Emissions have been reduced by 88% in the last 12 years



- ❑ Off-road, diesels nearly 100 percent of the off-road equipment used in construction
- ❑ In less than a decade (1996-2003)
 - PM reduced by 63%
 - NO_x reduced by 28%



This is not your Daddy's Diesel!

- ❑ High Efficiency(44 vs. 32 percent for production gasoline engines)
- ❑ “Rate shaped” direct fuel injection to reduce “clatter”
- ❑ No smoke
- ❑ Turbocharged for high power density (small engine)
- ❑ Rapid acceleration (0-60 mph in under 8 seconds)
- ❑ “Fun to drive”



Source: *DEER Conference*, Ride and Drive



Cummins anticipates that this diesel engine will provide an average of 30 percent fuel savings, ... over gasoline-powered engines for comparable vehicles.

The concept for this product is the result of a nine-year partnership between Cummins and the U.S. Department of Energy.

Cummins to Produce High-Performance, Light-Duty Diesel Engines

Cummins Press Release

Wednesday July 26, 8:32 am ET

Company to Partner with Major Automotive Manufacturer COLUMBUS, Ind.--(BUSINESS WIRE)--July 26, 2006-- Cummins Inc. (NYSE:CMI - News) today announced it has reached agreement with a major automotive manufacturer serving the North American market to produce and market a light-duty, diesel-powered engine. For competitive reasons, Cummins' original equipment manufacturer partner in the venture has asked to remain confidential.

As part of the agreement, Cummins will develop and manufacture a family of high-performance, light-duty diesel engines for a variety of automotive applications in vehicles below 8,500 pounds gross vehicle weight, including standard pickup trucks and sport utility vehicles. Certain bus, marine and industrial applications also will be served by this engine family.

The first vehicles with this engine are expected to be ready for market by the end of the decade. Cummins anticipates that this diesel engine will provide an average of 30 percent fuel savings, depending on the drive cycle, over gasoline-powered engines for comparable vehicles.

The concept for this product is the result of a nine-year partnership between Cummins and the U. S. Department of Energy. The DOE contract began in 1997 because of the federal agency's ongoing interest in energy efficiency in the automotive market.

"This agreement gives the driving public an even greater opportunity to experience the benefits of a new class of vehicles powered by a high-performance, fuel-efficient, clean diesel engine made by Cummins," said Tim Solso, Cummins Chairman and Chief Executive Officer.





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The Road to Clean Diesels

Aug 96

- DOE initiates Light Truck Clean Diesel Engine Program; issues NOPI



- EPA announces NPRM to limit diesel fuel sulfur levels

- EPA 2007-2010 HD diesel emissions final rule

- EPA final rule limiting diesel fuel sulfur to 15 ppm beginning in 2006



Jan 01

Dec 00

May 00

Mar 99

- EPA announces ANPRM on diesel fuel sulfur



Mar 98

- DOE initiates Diesel Emission Control – Sulfur Effects (DECSE) Program; EPA collaborates with DOE on DECSE

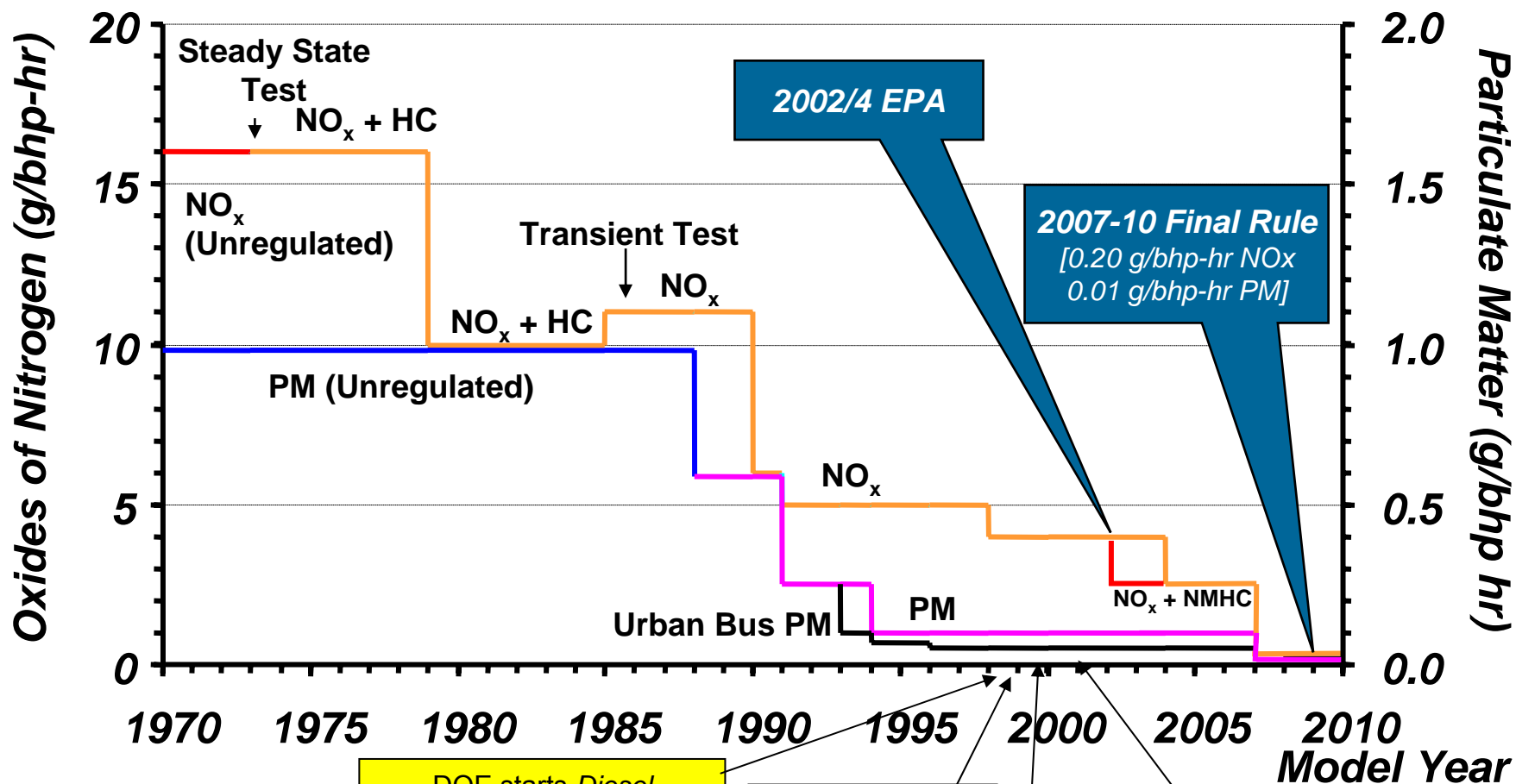
Jul 06

- Cummins announces agreement with major automaker to produce light-duty diesel engines for vehicles marketed by 2010





HD Diesel Engine Emissions Are Approaching Near Zero



DOE starts *Diesel Emission Control – Sulfur Effects (DECSE) Program*, (March 1998)

EPA collaborates with DOE in *DECSE Program*

EPA initiates ANPRM* on sulfur content in diesel fuel

EPA final rule on 2007-2010 HD diesel engine emissions and limiting diesel fuel sulfur to 15 ppm beginning in 2006 (Jan. 2001).

*Advanced Notice of Proposed Rulemaking



- ❑ Engine combustion control strategies are making impressive progress
 - Will reduce aftertreatment requirements
- ❑ NOx solutions are available for ultra-low emissions
 - Selective catalytic reduction (urea SCR) cold temperature and secondary emission issues are being addressed
 - Lean-NOx traps (LNT) performing well (about 60 to 70% efficiency)
- ❑ Diesel particulate filter (DPF) systems show continuous improvement
 - Very sophisticated regeneration control strategies

Source: T. Johnson, *Corning*, "Diesel Emission Control Technology Review," 2006
DEER Conference, Detroit, MI, August 20 – 24, 2006.



Engine combustion technology processes are changing

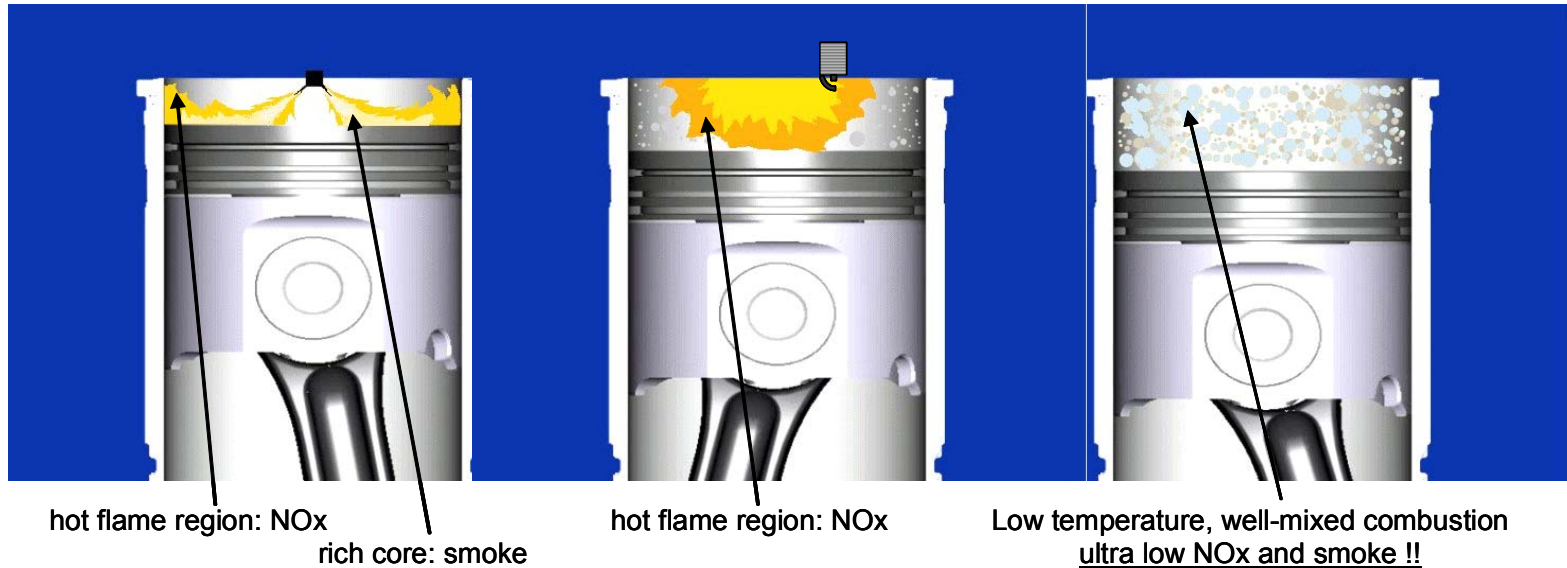
Stoichiometric → lean burn
(gasoline) GDI

CIDI (diesel) → HCCI
LTC
PCI

Diesel
(compression ignition)

Gasoline
(spark ignition)

HCCI
(Homogeneous Charge
Compression Ignition)



GDI – gasoline direct injection
CIDI – compression ignition direct injection

LTC – low temperature combustion
PCI – pre-mixed compression ignition



- ❑ Apply incremental technologies to U.S. 2007 compliant engines and add appropriate NO_x control in addition to exhaust gas recirculation (EGR)
 - Reduce NO_x from 1.0 g/bhp-hr to nominally 0.7 g/bhp-hr
 - 80 – 85% NO_x efficiency urea SCR can reduce NO_x levels of 1.0 to 1.3 g/bhp-hr engine out to 2010 compliance levels

Source: T. Johnson, *Corning*, "Diesel Emission Control Technology Review,"
2006 DEER Conference, Detroit, MI, August 20 – 24, 2006.



- ❑ More advanced engine combustion technology may be able to drive NO_x down to 0.5 g/bhp-hr (engine out)
 - High exhaust gas recirculation (EGR), very high pressure fuel injection equipment (FIE), high efficiency turbo “boost”, control systems
 - Requires 60 percent NO_x control (LNT)
 - SCR will allow 1.0 – 1.3 g/bhp-hr engine out NO_x, with fuel economy gains

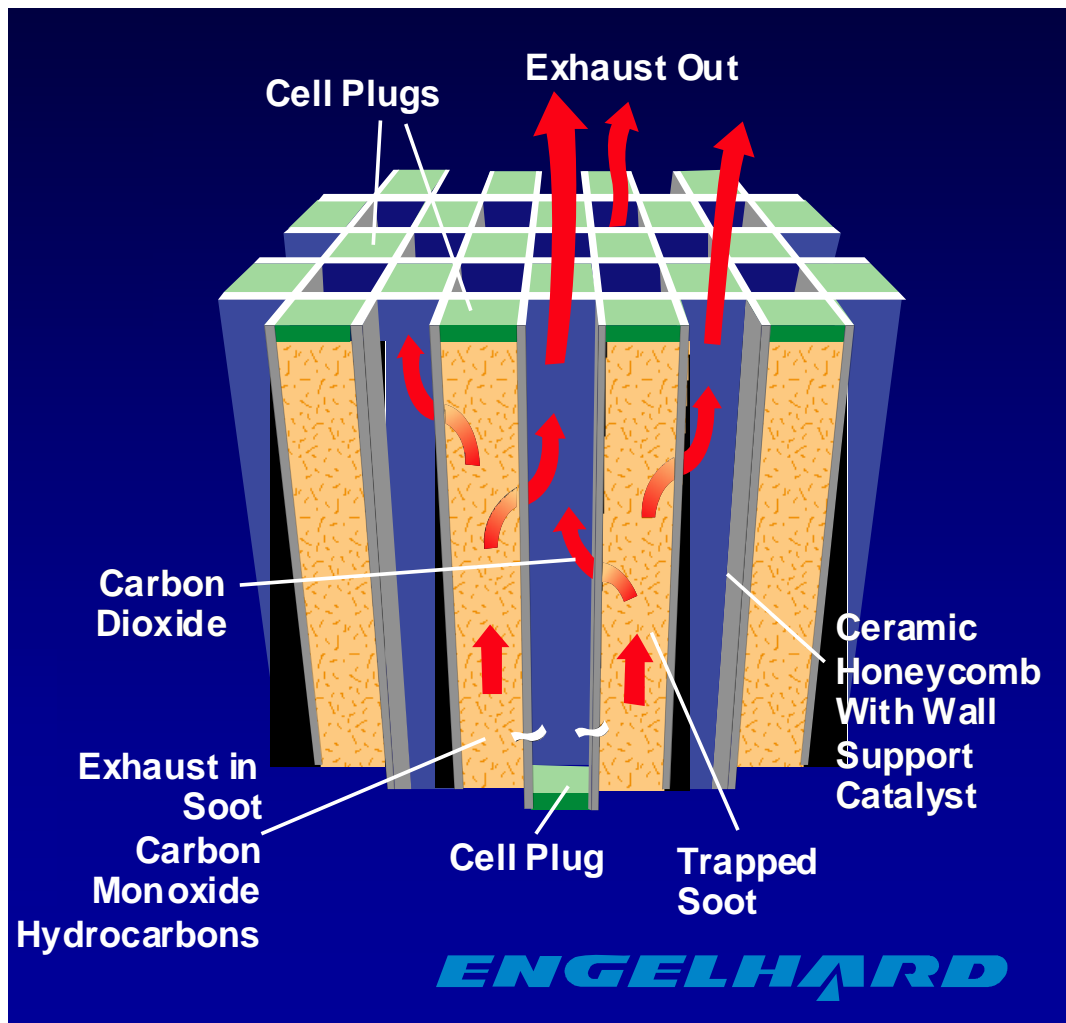
Source: T. Johnson, *Corning*, “Diesel Emission Control Technology Review,”
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Catalyzed Diesel Particulate Filter





CSF cleans up exhaust



- Collected mass reduced by 75%-90%
- No extractable organics on downstream filter
- All soot (elemental) carbon removed

Source: Oak Ridge National Laboratory

- Number concentration of very smallest particles may increase
- Micro-analysis indicates CSF particles are not soot carbon and are volatile
- Dilution tunnel affects size distribution
- *Smallest particles approach size of gas clusters as dilution increases*

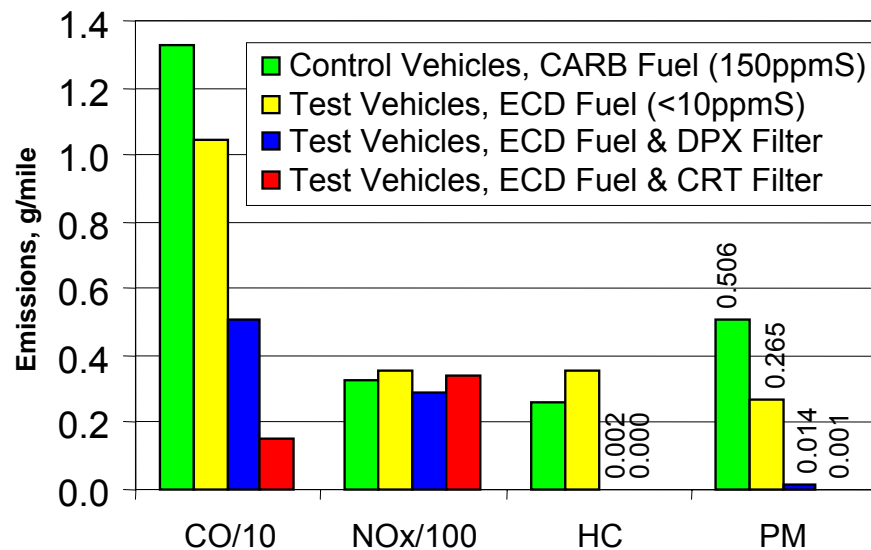


Very Effective in Reducing Heavy Truck PM Emissions

- ❑ Year long evaluation of ultra-low sulfur diesel fuel and diesel particulate filters on six truck and bus fleets
- ❑ Over 90% PM reduction with essentially no PM filter deterioration
- ❑ Led to commercialization of ultra-low sulfur diesel fuel and CARB verification in California
- ❑ DECSE Partners: DOE, ARCO/BP, Detroit Diesel, International, Cummins, Engelhard, Johnson Matthey, Ford, CARB, EPA, SCAQMD, CEC



Average Grocery Truck Emissions,
After 1 Year and 100,000 miles per truck





- ❑ U.S. oil dependence is driven by the transportation sector.
- ❑ Combustion engines are still the most viable for transportation considering the advantages of petroleum fuels over other alternative energy sources.
- ❑ There are fuel economy, durability, and other advantages offered by diesels over gasoline engines that motivate work on clean diesels.
- ❑ Progress in diesel emissions control will continue to make heavy duty clean diesels viable for commercial applications and light duty diesels viable for passenger cars and light trucks.
- ❑ New low temperature combustion regimes promise even higher diesel efficiency and lower engine-out emissions.